

## Description

Support with solder ball elements and method for loading substrates with ball contacts

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The invention relates to a support with solder ball elements for loading substrates with ball contacts. In this connection, the expression substrate is understood as meaning the components in semiconductor manufacture to which solder ball elements are to be applied in a predetermined arrangement pattern, such as semiconductor wafers with many semiconductor chip positions, individual semiconductor chips, intermediate wiring boards of semiconductor stack components, wiring boards of individual semiconductor components and/or printed circuit boards of a panel which may have a multiplicity of semiconductor component positions.

The term ball contacts is understood as meaning contacts such as extremely small flip-chip contacts with outer dimensions of a few micrometers through to contacts such as the intermediate contacts in semiconductor component stacks with outer dimensions in the millimeter range. While the flip-chip contacts are positioned on contact areas of, for example,  $42 \times 42 \mu\text{m}^2$  (square micrometers) of a semiconductor wafer or a semiconductor chip, the intermediate contacts span the distance between the underside and the upper side of a semiconductor package in a semiconductor stack component and may reach outer dimensions of several millimeters. Between these two extreme outer dimensions lie the outer dimensions of the external contacts for semiconductor components with BGA (ball grid array) packages, which today are in widespread use.

Nevertheless, the loading of a substrate with ball contacts of this type is difficult, the degree of difficulty involved in specific mounting, and consequently the number of rejects, increasing as the

dimensions become smaller, especially since the number of ball contacts to be applied also increases. The loading methods previously used are laborious and cost-intensive. A method of this type provides that the solder ball elements for ball contacts are shaken into depressions of a female mold and, as soon as all the depressions of a prescribed arrangement pattern are filled with solder ball elements, the solder ball elements in the depressions of the female mold can be connected to a corresponding pattern of contact areas on the substrate, for example by being simultaneously soldered on together. This technique is particularly problematical if an entire semiconductor wafer is to be provided with solder ball elements, especially since the number of solder ball elements to be applied simultaneously runs into the thousands.

The object of the invention is to provide a method for loading substrates with solder ball elements which overcomes the difficulties of the known methods, permits increased reliability of the loading of substrates with solder ball elements and provides a support with solder ball elements which makes a freely selectable arrangement pattern possible. By contrast with female molds with depressions, it is intended that the support with solder ball elements can be produced at low cost and permits a rapid design change to be made in the arrangement pattern for solder ball elements for different arrangement patterns of contact areas on substrates.

This object is achieved by the subject matter of the independent claims. Advantageous developments of the invention are provided by the dependent claims.

According to the invention, a support or carrier with solder ball elements for loading or populating substrates with ball contacts is provided. The support has a layer of adhesive applied on one side. The layer of adhesive comprises a thermoplastic or thermosetting

material, the adhesive force of which is reduced when irradiated. Furthermore, the support has solder ball elements which are arranged closely packed in rows and columns on the layer of adhesive. This close packing  
15 has the solder elements in the rows and columns in a prescribed minimally permissible pitch for a semiconductor chip or a semiconductor component.

One advantage of this support with solder ball elements  
10 is that it offers ball elements with the minimum permissible pitch for all the positions that are possible on a semiconductor chip or semiconductor component. Furthermore, it is an advantage of this support which has these closely packed solder ball  
15 elements that the adhesive force of the layer of adhesive is reduced when irradiated. Consequently, by selective irradiation of individual positions of solder ball elements, the solder ball element located there can be loosened at its position or even made to drop  
20 off. Even loosening of the solder ball elements is sufficient for the loosened solder ball elements to be removed from their positions by simple shaking or by other means of assistance, and to obtain with the remaining solder ball elements an arrangement pattern  
25 that has solder ball elements precisely where corresponding contact areas of a substrate are arranged. By keeping supports with rows and columns of closely packed solder ball elements, but with different minimal pitches, a supply of supports for a wide  
30 variety of types of application can be advantageously kept.

In a preferred form of the support, it is adapted to a substrate to be loaded in the form of a semiconductor  
35 wafer. In this case, the support has an arrangement pattern for flip-chip contacts for a multiplicity of semiconductor chips on the semiconductor wafer. In all the solder ball positions of the support provided for it, those solder ball elements for which no contact  
40 area is provided on the semiconductor wafer are

loosened and removed by irradiating the layer of adhesive.

15 In a further embodiment of the invention, the support is adapted to the arrangement pattern for flip-chip contacts of a semiconductor chip, so that semiconductor chips can be provided with flip-chip contacts in an efficient way. Here again, it is possible to use a then standardized support with a standardized pitch for  
10 the solder ball elements, which can be modified according to requirements to ball contacts for the semiconductor chip by irradiating individual solder ball element positions.

15 In the case of a further embodiment of the invention, it is provided that the printed circuit board of a panel is provided as the substrate to be loaded. For this purpose, the support has an arrangement pattern for ball contacts of a multiplicity of semiconductor  
20 components of the panel. This embodiment has the advantage that all the required external contacts of the semiconductor components for a panel can be applied to the panel simultaneously and together by one method step.

25 Furthermore, it is provided that the substrate to be loaded is a wiring support of a semiconductor component. In this case, the support has an arrangement pattern for external contacts of a  
30 semiconductor component. External contacts of this type of a semiconductor component are larger than flip-chip contacts of a semiconductor chip. Accordingly, the minimum pitch in which the solder ball elements are arranged on the support is also greater.

35 Finally, it is envisaged to provide an intermediate wiring board with appropriate stack contacts as the substrate to be loaded. Stack contacts of this type have outer dimensions which correspond to the thickness  
40 of one of the semiconductor components to be stacked

and respectively make a metallic external contact area available on the upper side and the underside of a semiconductor component, so that a via hole through the semiconductor stack from top to bottom or from bottom to top becomes possible by way of the stack contacts. For this purpose, the stack contacts have outer dimensions which are greater than the thickness of a semiconductor chip and may reach the outer dimensions of a thickness of a semiconductor component.

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A further aspect of the invention concerns a system for loading substrates with ball contacts. This system has a support with a layer of adhesive on one side, the layer of adhesive being a thermoplastic or thermosetting material, the adhesive force of which is reduced when irradiated. Furthermore, the system has ball elements which are arranged closely packed in rows and columns on the layer of adhesive in prescribed minimally permissible pitches for a semiconductor chip or a semiconductor component.

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Apart from the support with the solder ball elements, the system has an irradiating device with a source of radiation. Finally, the system has a removal device for removing the loosened solder ball elements while leaving solder ball elements in an arrangement pattern for flip-chip contacts or ball contacts. This removal device for removing the loosened solder ball elements may be formed in various preferred ways, as described in more detail below.

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Apart from the removal device for removing loosened solder ball elements, the system comprises a loading device for fixing the solder ball elements remaining in a predetermined arrangement pattern on the support on corresponding contact areas of the semiconductor wafer or of the semiconductor chip or of a wiring support for a semiconductor component. In addition, the system has a pulling-off device for pulling the support off the ball contacts as soon as the latter are connected to

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the contact areas of the substrates in the loading device.

This system has the advantage that it only has to have  
5 few components to accomplish relatively complex contact  
arrangement patterns on corresponding substrates. In  
addition, the system has the advantage that it can be  
made available at extremely low cost. And finally, the  
system has the advantage that it can also be divided  
10 into subgroups, one of the subgroups merely producing  
the standard supports with closely packed solder ball  
elements. Another component undertakes the patterning  
to form an arrangement pattern, and only in a further  
component is the substrate brought together with the  
15 support for loading with solder ball elements.

In a preferred embodiment of the invention, the  
irradiating device has a laser beam source. With the  
aid of corresponding deflecting devices, the laser beam  
20 source can perform selective irradiation of the support  
at intended positions by scanning of the laser beam. A  
method variant of this type has the advantage that no  
masks have to be provided for selective irradiation of  
the support, but it is merely necessary instead for the  
25 scanning of the laser to be correspondingly programmed.  
Consequently, the solder ball elements of the support  
are loosened at all the exposed positions and  
irradiation by the laser is suppressed at the positions  
at which the solder ball elements are required for an  
30 arrangement pattern of ball contacts on corresponding  
substrates.

In the case of a further embodiment of the system, the  
irradiating device has a UV source. This UV source  
35 irradiates the support over a surface area, so that the  
system additionally has a mask holder, which is  
provided between the UV source and the support for  
selective irradiation of the support at intended  
positions. This mask holder has masks which allow UV  
40 rays onto the support, and consequently onto the layer

of adhesive, only at the positions at which solder ball elements are to be loosened or removed.

Furthermore, it is provided that the system has a  
5 removal device for removing the loosened solder ball  
elements, which in a preferred embodiment of the  
invention has a roller or a continuous tape. This  
roller or this continuous tape is provided with a tacky  
surface, so that the loosened solder ball elements to  
10 be removed remain adhesively attached on the tacky  
surface. This removal device has the advantage that  
the solder ball elements loosened by irradiation of the  
adhesive location can be removed relatively gently and  
reliably transported away, since they remain attached  
15 on the tacky surfaces of the continuous tape or the  
roller.

In a further embodiment of the system, it is provided  
that the removal device for removing the loosened  
20 solder ball elements has a roller or a continuous tape  
on the upper sides of which stripping bristles are  
provided. With stripping bristles of this type, the  
loosened solder ball elements are indeed removed, but  
it may happen that during the stripping operation  
25 solder balls can get into the system and hinder  
operation. In this respect, the removal device  
additionally has a container surrounding the stripping  
device, which catches and collects all the solder ball  
elements detached by the stripping bristles. The balls  
30 that are caught can then be used again for loading a  
support with a closely packed arrangement of solder  
ball elements.

Apart from a possible holder for masks and holders for  
35 the removal device and irradiating device, the loading  
device additionally has a holder for the substrates to  
be loaded. In addition, the system has a support  
holder for the support with an arrangement pattern of  
solder ball elements. Both are aligned in the loading  
40 device with the aid of adjusting means in such a way

that the remaining solder ball elements of the support in the support holder can be aligned with contact areas of the substrates to be loaded in the substrate holder. Only after alignment of the support and substrate are the two brought together and can the solder ball elements be soldered onto the substrate at intended and aligned positions in a thermal step.

A method for loading substrates with ball contacts has the following method steps. Firstly, a tape with a layer of adhesive on one side, which comprises a thermoplastic or thermosetting material, the adhesive force of which is reduced when irradiated, is produced from a support material. Subsequently, solder ball elements are arranged on this tape, on the layer of adhesive, in rows and columns in a prescribed minimally permissible pitch for a semiconductor chip or for a semiconductor component.

This support tape, closely packed with solder ball elements, is subsequently selectively irradiated to reduce the adhesion of the layer of adhesive and to loosen solder ball elements at intended positions. Subsequently, the loosened solder ball elements are removed while leaving solder ball elements fixed on the support in an arrangement pattern for a semiconductor chip or for a semiconductor component. After an adjustment of the support prepared in this way, with solder ball elements at predetermined positions, said support is aligned with respect to a substrate with contact areas for applying solder ball elements and soldering them on to form ball contacts. This is followed by soldering the solder ball elements remaining in a prescribed arrangement pattern on the support onto contact areas of a semiconductor wafer or semiconductor chip or onto a wiring support for semiconductor components. In this way it is also possible for large-volume solder ball elements for intermediate contacts of a semiconductor stack

component to be prepared and soldered on at the corresponding positions.

After the soldering-on, the pulling-off of the support  
5 from the substrate loaded with flip-chip contacts or  
with ball contacts is performed. This may be assisted  
by the entire surface area of the support being  
irradiated, for example by a UV source. However,  
pulling-off of the support while the substrate is being  
10 heated is also possible.

For applying the layer of adhesive to the support  
material, a spraying process may be provided. It is  
also possible for the layer of adhesive to be rolled  
15 onto a support material.

The solder ball contact elements may be adhesively  
attached onto the layer of adhesive in rows, from  
dispensing nozzles arranged in parallel next to one  
20 another, in a prescribed minimally permissible pitch  
for a semiconductor chip or a semiconductor component.  
Dispensing nozzles of this type may take the form of  
pipettes, in the capillaries of which the solder ball  
elements are stacked. To reduce the adhesion of the  
25 layer of adhesive, UV rays or laser beams may be  
selectively made to act on the support and/or the layer  
of adhesive at the prescribed positions, so that only  
solder ball elements that do not match the arrangement  
pattern of the contact areas on a substrate are  
30 removed.

As already mentioned above, the lifting-off of the  
support material from the soldered-on ball contacts may  
be carried out by irradiating the support material over  
35 a large surface area.

To sum up, it can be stated that, with the support  
according to the invention, the so-called "ball apply  
process" or the so-called "bumping method" can be made  
40 significantly easier by the use of the support

according to the invention, since it is no longer necessary for a so-called "tool" to be made specifically for each "ballout". Consequently, the process times are also reduced, in particular in the case of so-called "wafer bumping" or "wafer ball apply".

By applying solder ball elements or so-called "balls" to the full surface area of a layer of adhesive of a support which is of such a nature that, under the influence of appropriate heat and/or radiation, it loses the adhesive force at the irradiated areas, it is possible to accomplish prescribed arrangement patterns for the ball contacts of semiconductor chips, semiconductor wafers, semiconductor components or else of stacked components in a precise and simple manner. In principle, all the desired "ballouts" can be accomplished. A flux possibly required for the soldering-on may be applied directly to the remaining "balls/bumps". Alternatively, the flux coating may also be applied to the contact areas or "bond pads". Consequently, the support according to the invention and the system according to the invention for loading the support and the method for loading substrates with ball contacts, the so-called "balls", produce the following advantages:

1. universally usable support for all ball sizes;
2. universal replication of various contact ball pitches, which can also be combined on a single support;
3. use of continuous tapes is possible,
4. use of films is possible;
5. in principle, any arrangement pattern or any "ballout" can be accomplished;
6. very great accuracy can be accomplished by the possibility of photolithographic processes, for example with selective irradiation;
7. in the case of large surface areas, such as surfaces of semiconductor wafers, loading with ball contacts,

known as "balling", is possible by a single process step;

8. flux can be applied directly to the solder ball elements of the support, without an additional tool  
5 being necessary.

The invention is now explained in more detail on the basis of the accompanying figures.

- 10 Figure 1 shows a schematic view from below of a support with solder ball elements according to a first embodiment of the invention;

- Figure 2 shows a schematic view from below of a  
15 support with solder ball elements after patterning of the support of Figure 1 to form an arrangement pattern of the solder ball elements;

- 20 Figure 3 shows a schematic cross section of a support through a column of solder ball elements;

- Figure 4 shows a cross section of an arrangement for  
25 selectively irradiating the layer of adhesive of the support;

- Figure 5 shows a schematic cross section of an  
arrangement for selectively coating a wiring  
substrate with ball contacts;

- 30 Figure 6 shows irradiation of the support over a large surface area for separating the support and the ball contact elements;

- 35 Figure 7 shows a schematic cross section through a semiconductor component with a semiconductor chip using a flip-chip technique, both the flip chip contacts and the external contacts of the semiconductor component being

positioned with the aid of supports according to the invention;

5        Figure 8 shows a schematic cross section through a semiconductor stack component with stack contacts, which permit the connection between the underside and upper side of the semiconductor stack component of the stack.

10      Figure 1 shows a schematic view from below of a support 4 with solder ball elements 1 according to a first embodiment of the invention. On its underside, the support 4 has a layer of adhesive 5, which has reduced adhesion for the solder ball elements 1 arranged on the  
15      layer of adhesive 5 when it is exposed to the effect of irradiation or heat. The solder ball elements 1 are arranged on the layer of adhesive 5 of the support 4 in rows 6 and columns 7 in a pitch w both in the direction of the rows 6 and in the direction of the columns 7.  
20      The support 4 is formed as a continuous tape, the portion of the continuous tape shown in Figure 1 having been chosen to match a substrate on the contact areas of which solder ball elements are to be soldered on at predetermined positions 1 to form ball contacts.

25      A support 4 of this type may be produced by firstly a support material being provided with the layer of adhesive 5 of a thermosetting or thermoplastic material and the solder ball elements 1 fixed on the layer of  
30      adhesive 5 row by row from a pipette assembly. A pipette assembly of this type can supply the solder ball elements 1 of a row 6 at the correct time via the cannulas of the pipettes. It is also possible by means of a vacuum pipette assembly to hold the solder ball  
35      elements 1 of a row 6 respectively at the mouthpieces of the vacuum pipettes until they are fixed on the layer of adhesive 5 of the support 4.

40      Figure 2 shows a schematic view from below of a support 4 with solder ball elements 1 after patterning of the

support 4 of Figure 1 to form an arrangement pattern 11 of the solder ball elements 1. This arrangement pattern 11 corresponds to a contact area pattern of a substrate which is to be loaded with the solder ball elements 1 shown in Figure 2. For this purpose, the solder ball elements 1 of this arrangement pattern 11 may firstly be brought into contact with a flux, which is applied to the solder ball elements 1 for example by a die or by a roller.

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With the figures which follow, it is explained how an arrangement pattern 11 of this type can be produced and how this patterning of solder ball elements is subsequently soldered onto contact areas of a substrate to form ball contacts. The designations shown in Figure 2 and the figures which follow are no longer explained if the components of these designations perform the same functions as in Figure 1.

20 Figure 3 shows a schematic cross section of a support 4 through a column 7 of solder ball elements 1. In the case of this support 4, each possible position is occupied by a solder ball element 1 in a pitch  $w$ , so that the column 7 is initially completely occupied with solder ball elements 1, the layer of adhesive 5 ensuring that the solder ball elements 1 are fixed in their position.

Figure 4 shows a cross section of an arrangement for selective irradiation of a layer of adhesive 5 of the support 4. In this case, the irradiation is performed by a large-area source of UV radiation, which irradiates in directions of arrows A a mask 18 of a system for loading substrates with ball contacts. This mask 18 irradiates in the direction of arrow B only the positions of the solder ball elements 1 of the support 4 that are to be removed from the support 4 in the direction of arrow C. The other solder ball elements 1 are protected by the mask 18 from being irradiated with UV light. Consequently, after the end of this process,

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the solder ball elements in a position not affected by the UV rays A remain on the adhesive layer 5. A mask 18 of this type can be prepared in a precise manner with the aid of photolithography, so that an exact arrangement pattern of solder ball elements 1 on the support 4 remains after this step.

Figure 5 shows a schematic cross section of an arrangement for selectively irradiating a wiring substrate 2 with ball contacts. For this purpose, the arrangement pattern 11 of solder ball elements 1 of the support 4 is aligned with respect to the wiring substrate 2 until the solder ball elements 1 lie opposite the contact areas 17 of the wiring substrate 2. Then the support 4 with its arrangement pattern 11 of solder ball elements 1 is brought onto the wiring substrate 2 in the direction of arrow D and a soldering-on of the solder ball elements 1 is carried out in a soldering process to form contact balls on the wiring substrate 2 in the positions of the contact areas 17. The support 4 with its layer of adhesive 5 is then still present on the ball contacts and, as Figure 6 shows, must be removed.

Figure 6 shows a large-area irradiation of the support 4 for separating the support 4 and the ball contacts 3 of the wiring substrate 2. Components with the same functions as in the previous figures are identified by the same designations and are not separately explained. The large-area irradiation, for example with a UV source, is again illustrated by the arrows A, this time no mask being required, especially since all the remaining, still not irradiated positions of the layer of adhesive 5 are to be detached from the original solder ball elements.

Figure 7 shows a schematic cross section through a semiconductor component 9 with a semiconductor chip 8 using a flip-chip technique, both the flip-chip contacts 12 of the semiconductor chip 8 and the external contacts 14 of the semiconductor component 9

having been positioned with the aid of supports 4 according to the invention. The representation in Figure 7 is not true to scale, especially since the external contacts 14 on the underside 23 of the wiring substrate 2 have outer dimensions that are larger, for instance by an order of magnitude, than the flip-chip contacts 12 on the contact areas 17 of the semiconductor chip 8. In this embodiment of the invention, the semiconductor chip 8, with its flip-chip contacts 12, is surrounded by a polymer composition 19, which at the same time forms an upper part of the package of the semiconductor component 9.

The underside of the package is substantially formed by the wiring substrate 2, on which the external contacts 14 are arranged outward in a uniformly distributed manner, while the flip-chip contacts 12 are disposed on the basis of the position of the contact areas 17 of the semiconductor chip 8. In order nevertheless to connect the flip-chip contacts 12 electrically to the external contacts 14, the wiring substrate 2 has contact vias 20, which extend through the wiring substrate 2 and are connected by means of a wiring patterning 21 to external contact areas 22 on the underside 23 of the wiring substrate 2. The external contacts 14 are arranged on these external contact areas 22 by the technique described above with the aid of a support.

Figure 8 shows a schematic cross section through a semiconductor stack component 10 with stack contacts 16, which permit the connection between the underside 23 and the upper side 24 of a semiconductor stack component 10. The embodiment according to Figure 8 differs from the previous embodiments in that three completely different solder ball sizes are processed for the production of this semiconductor component 10, and accordingly three differently patterned supports with solder ball elements are also made available for the manufacture of this semiconductor component 10.

In the case of the stack contacts 16, the main concern is that the entire polymer composition 19 that forms the upper part of the package of the semiconductor stack component 10 is penetrated by the stack contacts 16. For this purpose, they are arranged in edge regions of the wiring substrate 2 around the semiconductor chip 8. Corresponding redistribution routing lines 25 ensure that the external contacts 14 and the stack contacts 16 are electrically connected to one another. By means of the contact vias 20, the flip-chip contacts 12 of the semiconductor chip 8 are additionally connected to the external contacts 14. It is consequently possible to arrange a multiplicity of the semiconductor stack components 10 one on top of the other and to connect them by means of the stack contacts 16 to the external contacts 14 of the semiconductor component stack 10.